D E C L A R A T I O N

In the matter of U.S. Patent Application Ser. No. 09/438,786 in the name of Kazuhiko HARA, et al.

I, Katsuomi ISOGAI, of Kyowa Patent and Law Office, 2-3, Marunouchi 3-Chome, Chiyoda-Ku, Tokyo-To, Japan, declare and say:

that I am thoroughly conversant with both the Japanese and English languages; and,

that the attached document represents a true English translation of Japanese Patent Application No. 322012-1998 filed on November 12, 1998.

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Dated: September 13, 2002

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Title of the Invention: CONTROLLING METHOD AND CONTROLLING UNIT OF FLUSHING OPERATION FOR INK-JET RECORDING APPARATUS

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[Title of the document] SPECIFICATION

[Title of the invention] CONTROLLING METHOD AND CONTROLLING UNIT OF FLUSHING OPERATION FOR INK-JET RECORDING APPARATUS

[claims]

[claim 1]

A controlling method of a flushing operation for an ink-jet recording apparatus having an ink-jet recording head, the ink-jet recording bead being mounted on a carriage for jetting ink particles from a nozzle to form images on a recording medium, the carriage being moved in a width direction of a recording sheet, a flushing region for receiving the ink particles when a flushing driving signal is given to the recording head being provided outside a printing region,

wherein the controlling method has a feature that when a flushing operation is conducted to the flushing region, the flushing operation is conducted according to such a driving condition that after a main ink particle is jetted, no minute ink particle is generated or some minute ink particles are generated but combined with the following main ink particle.

[claim 2]

A controlling unit of a flushing operation for an ink-jet recording apparatus having an ink-jet recording head, the ink-jet recording bead being mounted on a carriage for jetting ink particles from a nozzle to form images on a recording medium, the carriage being moved in a width direction of a recording sheet, a flushing region for receiving the ink particles when a flushing driving signal is given to the recording head being provided outside a printing region,

wherein the controlling unit has a flushing controlling means that gives the flushing driving signal to the recording head according to such a driving condition that after a main ink particle is jetted, no minute ink particle is generated or some minute ink particles are generated but combined with the following main ink particle, when a flushing operation is conducted to the flushing region.

[claim 3]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 2,

wherein the flushing driving signal given to the recording head by the flushing controlling means is a periodical signal of such a frequency that minute ink particles generated after a main ink particle are caught up with by and combined with the following main ink particle.

[claim 4]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 2,

wherein the flushing driving signal given to the recording head by the flushing controlling means is an exclusive driving signal only for a flushing operation wherein generation of minute ink particle is suppressed, the exclusive driving signal being different from that for forming images on the recording medium.

[claim 5]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 2 or 3,

wherein the flushing driving signal given to the recording head by the flushing controlling means is controlled in such a manner that a generated minute ink particle has an ink speed and an ink weight enough not to float even by disturbing environment.

[claim 6]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 2 or 3,

wherein the flushing driving signal given to the recording head by the flushing controlling means is controlled in such a manner that a generated minute ink particle has an ink speed of 4 m/s or more and an ink weight of 10 ng or more.

[claim 7]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 4,

wherein the flushing operation conducted by the exclusive driving signal is controlled to involve a larger amount of ink-jetting, compared with a driving condition wherein an image is formed on the recording medium.

[claim 8]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 7,

wherein the flushing operation involving a larger amount of ink-jetting is a flushing operation for preventing mix of colors that is to be conducted after a recovering operation wherein the ink is absorbed from the nozzle of the recording head and the ink is discharged from an ink passage in the recording head.

[claim 9]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to any of claims 2 to 8,

wherein one of the flushing region is a capping means that can seal a nozzle-formed surface of the recording head moved at a position outside the printing region.

[claim 10]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to any of claims 2 to 8,

wherein one of the flushing region is an opening disposed at a position outside the printing region, different from a capping means that can seal a nozzle-formed surface of the recording head.

[claim 11]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 10,

wherein a waste-ink absorbing member for absorbing and holding waste ink is provided in the opening at a portion opposite the nozzle-formed surface of the recording head, and the distance between the waste-ink absorbing member and the nozzle-formed surface of the recording head is such a distance that minute ink particles generated from the recording head in the flushing operation are not dispersed.

[claim 12]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to any of claims 2 to 11,

wherein the ink-jet recording apparatus is a color recording apparatus for forming an image on the recording medium by jetting a plurality of color inks from nozzles of the recording head, and the flushing controlling means gives the flushing driving

signal to the recording head according to different driving conditions dependent on types of ink.

[claim 13]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to any of claims 2 to 12,

wherein the ink-jet recording apparatus is a color recording apparatus for forming an image on the recording medium by jetting a plurality of color inks from nozzles of the recording head, and the flushing controlling means conducts the flushing operation in different flushing regions dependent on types of ink.

[claim 14]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to any of claims 2 to 13,

wherein the ink-jet recording apparatus further comprises a fan for preventing a temperature rise of the recording apparatus, and a fan control means is arranged for stopping the fan when the flushing operation is conducted by the flushing controlling means.

[claim 15]

A controlling unit of a flushing operation for an ink-jet recording apparatus according to claim 14,

wherein the fan control means keeps the fan stopped at least until the ink particles jetted in the flushing operation arrive at an opposite portion.

[Detailed description of the invention]

[0001]

[Field of the invention]

The present invention relates to a controlling method and a controlling unit of a flushing operation for an ink-jet recording apparatus having an ink-jet recording head, the ink-jet recording bead being mounted on a carriage for jetting ink particles from a nozzle to form images on a recording medium, the carriage being moved in a width direction of a recording sheet, a flushing region for receiving the ink particles when a flushing driving signal is given to the recording head being provided outside a printing region. In particular, the present invention relates to a

controlling technique for suppressing generation of unnecessary mist from minute ink particles during the flushing operation.

[0002]

[Prior art]

The ink-jet recording apparatus generates relatively low noise during a printing operation and is capable of forming small dots with a high density. Accordingly, the ink-jet recording apparatus is used prevalently in recent years for printing images including color images. The ink-jet recording apparatus comprises an ink-jet recording head supplied with the ink from an ink cartridge, and a sheet feeding means for moving a recording sheet relative to the recording head. A carriage mounted with the ink-jet recording head is moved in a direction along the width of the recording sheet and ink particles are jetted onto the recording sheet by the ink-jet recording head for recording. A full-color ink-jet recording apparatus is provided with black, yellow, cyan and magenta ink-jet recording heads mounted on a carriage and capable of jetting black, yellow, cyan and magenta ink particles, respectively. The full-color ink-jet recording apparatus is capable of full-color printing by jetting those color inks at appropriate ratios as well as text printing for forming black letters.

[0003]

The ink-jet recording head jets ink particles by pressure produced in a pressure chamber through nozzles onto a recording sheet for printing. Therefore, it is possible that operation of the ink-jet recording head results in faulty printing due to the increase of the viscosity of the ink or the solidification of the ink, resulting from the evaporation of the solvent through the nozzles. Faulty printing will be caused also by adhesion of dust to the nozzles or formation of bubbles in the ink. Thus, the ink-jet recording apparatus is provided with a capping means for sealing up the openings of the nozzles of the recording head when the recording head is not in printing operation, and a cleaning device for cleaning a nozzle plate when necessary. The capping means functions as a cover for preventing the ink from drying in the nozzles while the ink-jet recording apparatus is not in

printing operation. The capping means further has a function to remove the ink solidified in the nozzles and clogging the same and to remove bubbles formed in ink passages and causing a faulty ink jetting operation, by bringing the capping means in close contact with the nozzle plate and by applying a negative pressure from a suction pump to the nozzles to suck out the ink clogging the nozzles, when the nozzles are clogged.

[0004]

The suction discharging operation for forcibly sucking out the ink from the clogged nozzles of the recording head and for removing bubbles from the ink passages is called generally a cleaning operation. The cleaning operation is carried out before resuming the printing operation after the long interruption of the printing operation. The cleaning operation is also carried out when an operator operates a cleaning switch to resolve the deterioration of the print quality of printed images. The cleaning operation is accompanied with a wiping operation for the surface of the recording head with a wiping member consisting of elastic plates such as rubber plates, after discharging the ink from the nozzles by the negative pressure.

[0005]

The recording head has a function to jet ink particles when applied a driving signal unrelated with printing operation. This jetting operation is called generally a flushing operation. The flushing operation is performed to regulate menisci of the ink at the outlet openings of the nozzles of the recording head when the menisci are disturbed by the wiping operation after the cleaning operation. The flushing operation is also performed to discharge the mixed ink forced to flow reverse into the nozzles by the wiping operation, from the nozzles. The flushing operation is performed periodically to prevent the nozzles through which only a small amount of the ink is jetted during the printing operation from being clogged with the ink due to increase in the viscosity of the ink.

[0006]

[Problems to be solved by the invention]

The ink-jet recording apparatus is provided with, for

example, a recording head as shown in Fig. 10. Fig. 10 is a sectional view showing one of ink passages of a recording head 5. A practical multinozzle recording head 5 has nozzles arranged in rows, each of which rows is formed by combining an ink passage and a nozzle shown in the drawing.

[0007]

In the drawing, the reference sign 5a designates a vibrating plate. A lower electrode 5b is formed on a surface of the vibrating plate 5a. A piezoelectric member 5c, such as a PZT, is placed on the surface of the lower electrode 5b. An upper electrode 5d is arranged on a surface of the piezoelectric member 5c. The piezoelectric member 5c expands or contracts by a driving signal applied thereto through the lower electrode 5b and the upper electrode 5d, and then the vibrating plate 5a is driven for vertical movement in the drawing.

[0008]

A spacer 5e underlies the vibrating plate 5a. The spacer 5e forms a cavity (pressure chamber) 5f under the vibrating plate 5a on which the piezoelectric member 5c is arranged. An ink supply port forming plate 5g underlies the spacer 5e. The plate 5g is provided with an ink supply port 5h opening into the cavity 5f. A spacer 5i underlies the ink supply port forming plate 5g. The spacer 5i forms a common ink chamber, that is, a reservoir 5j.

[0009]

A nozzle plate 5m provided with a nozzle 5k underlies the spacer 5i. The spacer 5e, the ink supply port forming plate 5g and the spacer 5i are provided with openings forming an ink passage 5n extending between the cavity 5f and the nozzle 5k. The spacer 5e, the ink supply port forming plate 5g and the spacer 5i are bonded together with adhesive layers.

[0010]

In the above structure, the vibrating plate 5a vibrates vertically in the drawing, by the expansion and contraction of the piezoelectric member 5c. When the vibrating plate 5a moves vertically downward, pressure is applied to the ink contained in the cavity 5f to force the ink to flow through the ink passage 5n and the ink is jetted through the nozzle 5k as ink particles.

When electric charges are discharged from the piezoelectric vibrating member 5c, the vibrating plate 5a returns to an original state thereof. Consequently, the cavity 5f expands, the ink is supplied from the ink reservoir 5j, which forms the common ink chamber, through the ink supply port 5h into the cavity 5f to replenish the cavity 5f with the ink for the next printing cycle.

[0011]

Thus, the piezoelectric member 5c is repeatedly moved to replenish the cavity 5f with the ink supplied from the ink reservoir 5j and to jet the ink supplied from the cavity 5f through the ink passage 5n through the nozzle 5k as ink particles.

[0012]

Fig. 11 shows the behavior of ink particles, for example jetted in the flushing operation. At first, as shown in Fig. 11(a), a main ink particle M and an ink string following the main ink particle M are spewed out from the nozzle 5k when the volume of the cavity 5f is reduced. A part of the ink string following the main ink particle M changes into a plurality of minute ink particles S because of the surface tension of the ink as shown in Fig. 11(b). Generally, the minute ink particles S shown in Fig. 11(c) fly at low speed, have very small weight and are liable to float in air as unnecessary ink mist. The ink mist may contaminate the interior of the recording apparatus, and may be discharged outside through an opening of the recording apparatus (for example, an exhaust opening for a cooling fan) to contaminate the peripheral equipment.

[0013]

Especially, as shown in Figs. 1 and 12, when the recording apparatus has a second flushing region 13 on the opposite side of the capping means with respect to a printing region, there is a limit to the amount of the flushing ink discharged into the capping means, and a large amount of flushing ink must be discharged into the second flushing region 13. In addition, when an opening is formed in a member (a sheet guide member) 8 disposed opposite to the nozzles of the recording head 5 as a structure of the second flushing region 13, as shown in Fig. 12, the distance between the nozzle-formed surface of the recording head 5 and an absorbing

member 14 for receiving the flashed ink is as long as several tens millimeters.

[0014]

When the ink absorbing member 14 is relatively distant from the nozzle-formed surface of the recording head 5 like the above case, the minute ink particles (satellite particles) S generated by the above action may drift away as shown by an arrow, before the same reach the ink absorbing member 14 which is arranged on the bottom of the opening 13. Then, the drifting minute ink particles S may contaminate the peripheral components. Particularly, the foregoing problem is conspicuous in the recent recording apparatus which controls the volume of each ink particle to the least possible volume in order to print images with high print quality. Ink particles jetted through the nozzles are charged to a not small extent and it is possible that ink particles are accelerated by static electricity generated by a driving unit included in the recording apparatus. In addition, it is possible that the jetted ink particles are accelerated by air currents generated by an exhaust fan, which is disposed to suppress the temperature rise in the recording apparatus.

[0015]

The present invention has been made in view of the foregoing problems and it is therefore an object of the present invention to provide a flushing controlling method and a flushing controlling unit in an ink-jet recording apparatus capable of effectively suppressing the formation of minute ink particles that may float in mist especially during a flushing operation, and thus to provide an ink-jet recording apparatus capable of preventing the contamination of the ink-jet recording apparatus itself and the peripheral equipment.

[0016]

[Means for solving the problems]

A controlling method of a flushing operation for an ink-jet recording apparatus according to the invention created for achieving the above object is: a controlling method of a flushing operation for an ink-jet recording apparatus having an ink-jet

recording head, the ink-jet recording bead being mounted on a carriage for jetting ink particles from a nozzle to form images on a recording medium, the carriage being moved in a width direction of a recording sheet, a flushing region for receiving the ink particles when a flushing driving signal is given to the recording head being provided outside a printing region, wherein when a flushing operation is conducted to the flushing region, the flushing operation is conducted according to such a driving condition that after a main ink particle is jetted, no minute ink particle is generated or some minute ink particles are generated but combined with the following main ink particle.

[0017]

In addition, a controlling unit of a flushing operation for an ink-jet recording apparatus according to the invention is: a controlling unit of a flushing operation for an ink-jet recording apparatus having an ink-jet recording head, the ink-jet recording bead being mounted on a carriage for jetting ink particles from a nozzle to form images on a recording medium, the carriage being moved in a width direction of a recording sheet, a flushing region for receiving the ink particles when a flushing driving signal is given to the recording head being provided outside a printing region, wherein the controlling unit has a flushing controlling means that gives the flushing driving signal to the recording head according to such a driving condition that after a main ink particle is jetted, no minute ink particle is generated or some minute ink particles are generated but combined with the following main ink particle, when a flushing operation is conducted to the flushing region.

[0018]

In the case, preferably, the flushing driving signal given to the recording head by the flushing controlling means is a periodical signal of such a frequency that minute ink particles generated after a main ink particle are caught up with by and combined with the following main ink particle. In addition, it is also preferable that the flushing driving signal given to the recording head by the flushing controlling means is an exclusive driving signal only for a flushing operation wherein generation

of minute ink particle is suppressed, the exclusive driving signal being different from that for forming images on the recording medium.

[0019]

Furthermore, preferably, the flushing driving signal given to the recording head by the flushing controlling means is controlled in such a manner that a generated minute ink particle has an ink speed and an ink weight enough not to float even by disturbing environment. In the case, in a preferable example, the flushing driving signal given to the recording head by the flushing controlling means is controlled in such a manner that a generated minute ink particle has an ink speed of 4 m/s or more and an ink weight of 10 ng or more.

[0020]

The flushing operation conducted by the exclusive driving signal is preferably controlled to involve a larger amount of ink-jetting, compared with a driving condition wherein an image is formed on the recording medium. As an example, the flushing operation involving a larger amount of ink-jetting is a flushing operation for preventing mix of colors that is to be conducted after a recovering operation wherein the ink is absorbed from the nozzle of the recording head and the mixed ink in an ink passage of the recording head is discharged.

[0021]

As the flushing region, used is a capping means that can seal a nozzle-formed surface of the recording head moved at a position outside the printing region or an opening disposed at a position outside the printing region, different from the capping means.

[0022]

In a preferable embodiment of the present invention, a waste-ink absorbing member for absorbing and holding waste ink is provided in the opening at a portion opposite the nozzle-formed surface of the recording head, and the distance between the waste-ink absorbing member and the nozzle-formed surface of the recording head is such a distance that minute ink particles generated from the recording head in the flushing operation are

not dispersed. In the case, it is desirable that the distance is 20 mm or less.

[0023]

In addition, in a preferable embodiment of the present invention, the ink-jet recording apparatus is a color recording apparatus for forming an image on the recording medium by jetting a plurality of color inks from nozzles of the recording head, and the flushing controlling means gives the flushing driving signal to the recording head according to different driving conditions dependent on types of ink.

[0024]

In addition, in a preferable embodiment of the present invention, the ink-jet recording apparatus is a color recording apparatus for forming an image on the recording medium by jetting a plurality of color inks from nozzles of the recording head, and the flushing controlling means conducts the flushing operation in different flushing regions dependent on types of ink.

[0025]

In addition, if the ink-jet recording apparatus further comprises a fan for preventing a temperature rise of the recording apparatus, it is desirable that a fan control means is arranged for stopping the fan when the flushing operation is conducted by the flushing controlling means. In the case, it is desirable that the fan control means keeps the fan stopped at least until the ink particles jetted in the flushing operation arrive at an opposite portion.

[0026]

According to a flushing controlling method and a flushing controlling unit in a recording apparatus of the present invention as described above, the driving condition of the recording head by the flushing controlling means is determined in such a manner that no minute ink particle is generated during the flushing operation, that is, only main ink particles are jetted, so that the generation of ink mist can be effectively suppressed. In addition, even if a flushing operation is conducted in a condition wherein a minute ink particle is generated after a main ink particle, if the minute ink particle has an ink speed of 4 m/s or more and

an ink weight of 10 ng or more, the minute ink particle is not dispersed by disturbing environment, so that the generation of ink mist can be effectively suppressed as well.

[0027]

In addition, even if a flushing operation is conducted in a condition wherein a minute ink particle is generated after a main ink particle, if the jetted speed of the main ink particle is controlled and a driving condition is set, for example the frequency of the driving signal is set, in such a manner that the following main ink particle can combine with the preceding minute ink particles, the generation of ink mist can be effectively suppressed as well. As a result, the problem that the generated ink mist may cause the contamination of the interior and the exterior of recording apparatus can be solved.

[0028]

[Embodiments of the invention]

A controlling method and a controlling unit of a flushing operation for an ink-jet recording apparatus according to the invention is explained based on the embodiment shown in the drawings. Fig. 1 shows a structure of a main body of a recording apparatus according to the invention. In Fig. 1, the numeral sign 1 designates a carriage 1. The carriage 1 is reciprocated along a horizontal carriage guide rod 4 supported on a right side frame 3 and a left side frame 2, via a timing belt driven by a carriage motor, not shown.

[0029]

An ink-jet recording head 5 is mounted to the lower side of the carriage 1 so that nozzles face down. A black ink cartridge 6 and a color ink cartridge 7 containing inks to be supplied to the recording head 5 are detachably mounted on an upper portion of the carriage 1. A sheet guide member 8 is disposed below the recording head 5 along a direction in which the recording head 5 is moved. A recording sheet 9 as a recording medium is supported on the sheet guide member 8. The recording sheet member 9 is moved in a direction perpendicular to the moving direction of the recording head 5, by a sheet feeding means, not shown.

[0030]

A capping means 10 is disposed in a nonrecording region (home position). A nozzle plate as a nozzle-formed surface of the recording head 5 is sealed by the capping means 10 when the recording head 5 is moved just above the capping means 10. A suction pump 11 is disposed below the capping means 10, in order to evacuate the interior of the capping means 10 to generate a negative pressure therein.

[0031]

The capping means 10 functions as a cover for preventing the ink from drying in the nozzles of the recording head 5 while the ink-jet recording apparatus is not in operation. The capping means 10 functions further as an ink receiving member, that is, a first flushing region in a flushing operation in which a flushing signal unrelated with printing operation is given to the recording head 5 to make the recording head 5 jet ink particles in vain. The capping means 10 functions further as a suction means for sucking ink from the nozzles 5k by applying a negative pressure from the suction pump 11 to the recording head 5.

[0032]

A wiping member 12 consisting of elastic plates such as rubber plates is disposed near the capping means 10. The wiping member 12 performs a wiping operation for wiping the nozzle-formed surface of the recording head 5 when the carriage 1 moves toward and/or away from a position corresponding to the capping means 10.

[0033]

A second flushing region 13 is formed in another nonprinting region opposite the nonprinting region in which the capping means 10 is disposed. The second flushing region 13 consists of an opening formed in the sheet guide member 8. An ink absorbing member 14 is disposed on the bottom part of the opening 13 to absorb and hold the ink sucked from the interior of the capping means 10 by the pump 11. The ink absorbing member 14 is mounted in an absorbing-member housing case i.e. a waste ink tank 15 extended along the sheet guide member 8.

[0034]

Fig. 2 shows an example of a control circuit included in the ink-jet recording apparatus. In Fig. 2, the recording head 5, the ink cartridges 6 and 7, the capping means 10, the suction pump 11 and the waste ink tank 16 previously described with reference to Fig. 1 are designated by the same reference numerals and thus the description thereof is omitted.

[0035]

Referring to Fig. 2, a printing operation controlling means 30 produces bit-map data on the basis of printing data given thereto from a host computer system included in the ink-jet recording apparatus, and gives the bit-map data to a head driving means 31. The head driving unit 31 generates a printing signal on the basis of the bit-map data. The recording head 5 is driven by the printing signal to jet the ink. The head driving means 31 gives a flushing signal, in addition to the printing signal based on the printing data, to the recording head 5, the flushing signal being produced in response to a flushing request signal given from a flushing operation controlling means 32. The recording head 5 is driven by the flushing signal to jet the ink unrelated with printing operation in vain.

[0036]

A cleaning operation controlling means 33 gives a control signal to a pump driving means 34 to drive the suction pump 11. A control request signal is given to the cleaning operation controlling means 33 by the printing operation controlling means 30 and a cleaning-request detecting means (CL-request detecting means) 35. A switch 36 is connected to the cleaning-request detecting means 35. The switch 36 can be pushed by the operator. When the switch 36 is pushed, the cleaning-request detecting means 35 operates and initiates the manual cleaning operation.

[0037]

A carriage positioning controlling means 37 is connected to the flushing operation controlling means 32. When the flushing operation is requested, the flushing operation controlling means 32 gives a control signal to the carriage positioning controlling means 37 to drive a carriage motor 38 so that the recording head 5 mounted on the carriage 1 is moved just above the capping means

10 as the first flushing region or just above the opening 13 of the sheet guide member 8 as the second flushing region.

[0038]

A fan controlling means 39 is connected to the flushing operation controlling means 32. When the flushing operation is requested, the flushing operation controlling means 32 gives a control signal to the fan controlling means 39 to temporarily stop a fan motor 40 which drives a ventilation fan (not shown) for ventilating the interior of the ink-jet recording apparatus to suppress the temperature rise in the ink-jet recording apparatus.

[0039]

Fig. 3 is a circuit diagram of the control circuit for driving the recording head 6, i.e., the head driving means 31 shown in Fig. 2. A timing signal provided by the printing operation controlling means 30 or the flushing operation controlling means 32 is applied to an input terminal 50. The timing signal is transferred from the input terminal 50 to a one-shot multivibrator 51. Then, the one-shot multivibrator 51 provides a positive signal and a negative signal on its noninversion and inversion output terminals, respectively, synchronously with the inputted timing signal.

[0040]

A base terminal of an NPN transistor 52 is connected to the noninversion output terminal of the one-shot multivibrator 51. The collector terminal of the NPN transistor 52 is connected to the base terminal of a PNP transistor 53. The emitter terminal of the transistor 53 is connected through a charging resistor 54 and a FET 55 to a DC power supply VH. The collector terminal of the transistor 53 is connected to a second electrode of a capacitor 56, whose first electrode is connected to a reference potential point (ground).

[0041]

The base terminal and the emitter terminal of the transistor 53 are connected to the collector terminal and the base terminal of a PNP transistor 57, respectively. The emitter terminal of the PNP transistor 57 is connected to the DC power supply VH.

Thus, when the timing signal is applied to the input terminal 50 of the one-shot multivibrator 51, the capacitor 53 is charged by a fixed current I_r.

[0042]

An NPN transistor 58 has a base terminal connected to the inversion output terminal of the one-shot multivibrator 51, a collector terminal connected to the second electrode of the capacitor 56 whose first electrode is connected to the ground, and an emitter terminal connected through a discharge resistor 59 and a FET 60 to the ground. The base terminal and the emitter terminal of the transistor 58 are connected to the collector terminal and the base terminal of the NPN transistor 61, respectively. The emitter terminal of the transistor 61 is connected to the ground. Thus, upon the change of the timing signal applied to the input terminal 50 of the one-shot multivibrator 51, the capacitor 56 discharges a fixed current I_f.

[0043]

The charging-and-discharging terminal of the capacitor 56 is connected to a complementary type of current amplifier including a pair of an NPN transistor 62 and a PNP transistor 63. A common emitter terminal of the transistors 62 and 63 serves as an output terminal 64. A voltage obtained by amplifying the terminal voltage of the capacitor 56 appears on the output terminal 64.

[0044]

The charging current I_r for charging the capacitor 56 is expressed by:

$$I_r = V_{BE}\ 57/R_r$$

where V_{BE} 57 is the base-emitter voltage of the transistor 57, and R_r is the series combined resistance of the charging resistor 54 and the FET 55.

The rise time T_r of charging voltage is expressed by:

$$T_r = C_0 \times V_H/I_r$$

where C_0 is the capacitance of the capacitor 56.

[0045]

The discharge current I_f discharged by the capacitor 56 is expressed by:

$$I_f = V_{BE}\ 61/R_f$$

where V_{BE} 61 is the base-emitter voltage of the transistor 61, and R_f is the series combined resistance of the discharge resistor 59 and the FET 60.

The fall time T_f of discharging voltage of the capacitor 56 is expressed by:

$$T_f = C_0 \times V_H / I_f$$

[0046]

As shown in Fig. 4(a), the terminal voltage of the capacitor 56 has a trapezoidal waveform having a rising region rising at a fixed gradient α, a saturated region maintaining a fixed voltage (V_1), a falling region falling at a gradient β and a duration T1. This trapezoidal waveform is amplified by the transistors 62 and 63 and outputted as a driving signal to respective piezoelectric members 5c1, 5c2, 5c3, ... of the recording head connected to the output terminal 64.

[0047]

The other electrodes of the respective piezoelectric members 5c1, 5c2, 5c3, ... are connected to a switching circuit 65 comprising respective switching devices, such as transistors. The switching circuit 65 is controlled by a control signal provided by a control circuit 66 to selectively connect the other terminals of the respective piezoelectric members 5c1, 5c2, 5c3, ... to the ground.

[0048]

The control circuit 66 is adapted to output a positive pulse signal having positive pulses of a small pulse width (Fig. 4(c)) synchronously with the timing signal provided by the printing operation controlling means 30 or the flushing operation controlling means 32 on the basis of the request signal from the controlling means 30 or 32. Based on the positive pulse signal, the switching circuit 65 operates to connect the other terminals of the respective piezoelectric devices 5c1, 5c2, 5c3, ... to the ground.

[0049]

All the piezoelectric members 5c1, 5c2, 5c3, ... are charged when the voltage having the trapezoidal waveform (Fig. 4(a)) is applied thereto through the output terminal 64. When the positive

pulse signal shown in Fig. 4(c) falls during the charging of the piezoelectric members 5c, the switching circuit 65 goes OFF. Consequently, the charging of the piezoelectric members 5c1, 5c2, 5c3, ... is stopped at a voltage (V2) dependent on the charging time T3.

[0050]

Thus, a second driving signal (printing operation signal) having a trapezoidal waveform as shown in Fig. 4(b) can be generated by controlling the charging time to the respective piezoelectric members 5c1, 5c2, 5c3, ... In the case, a rising gradient α, a falling gradient β, and a duration T2 of the second driving signal are substantially the same as those of the first driving signal (flushing operation controlling signal) shown in Fig. 4(a).

[0051]

The piezoelectric members 5c1, 5c2, 5c3, ... are charged by a fixed current and discharge a fixed current when the first or the second driving signal are applied thereto. Consequently, the piezoelectric members 5c expand or contract to displace the vibrating plates 5a. Thus, the ink is supplied from the reservoir 5j of the recording head 5 to the cavities 5f, the ink in the cavities 5f is forced to flow through the ink passages 5m and is jetted as ink particles through the nozzles 5n.

[0052]

The control circuit 66 gives control voltages to the respective gates of the FET 55 for determining a charging-time constant and the FET 60 for determining a discharge-time constant. The substantial drain-source impedances (DC resistances) of the respective FETs 55 and 60 can be varied by controlling the voltages given to the respective gates of the FETs 55 and 60.

[0053]

For example, the DC combined resistance R_r of the charging resistor 54 and the FET 55 increases and the charging current I_r is reduced when the drain-source DC resistance of the FET 55 for determining the charging-time constant is increased. Therefore, as shown in Fig. 5, the rising gradient α of the trapezoidal waveform of the driving signal can be changed to a gradient α' as shown by a broken line.

[0054]

Similarly, the DC combined resistance R_f of the discharging resistor 59 and the FET 60 increases and the discharging current I_f is reduced when the drain-source DC resistance of the FET 60 for determining the discharging-time constant is increased. Therefore, the falling gradient β of the trapezoidal waveform of the driving signal can be reduced, which is not shown in Fig. 5. Thus, the rising gradient α of the trapezoidal waveform of the driving signal and the falling gradient β of the same can optionally be adjusted by adjusting the DC voltages given to the FETs 55 and 60.

[0055]

In the above ink-jet recording apparatus, the frequency of the driving signal is dependent on the frequency of the timing signal shown in Fig. 4(c), and the level of the driving signal is controlled according to the duration T_3 of the timing signal. The rising and falling gradients of the trapezoidal waveform of the driving signal can be controlled according to the DC voltages outputted to the FETs 55 and 60, respectively, by the control circuit 66.

[0056]

Control conditions for controlling the recording head 5 so that the recording head 5 may not generate satellite ink particles S explained with reference to Fig. 11 during the flushing operation can be determined by utilizing the foregoing control characteristic. For example, if the level of the driving signal given to the piezoelectric members is raised more gradually than the rise of the level of the driving signal for the usual ink-jetting operation to increase the pressure in the cavities 5f of the recording head 5 more gradually and the level of the driving signal is lowered rapidly, that is, as shown in Fig. 5, if the level of the driving signal is raised gradually at a rising gradient α' to the voltage V_1 and the level of the driving signal is lowered sharply at a falling gradient β, the ink-jetting action can be controlled more dull. In the case, the flying speed of main ink particles jetted from the nozzles can be controlled not higher than 5m/sec. In addition, it can be prevented that the satellite

ink particles are generated.

[0057]

Other experiments showed that, in situations wherein the satellite ink particles are generated, when the recording head 5 is controlled so that the satellite ink particles fly at speeds of 4 m/s or above and have weight of 10 ng or above, the satellite ink particles have such large momenta that the satellite ink particles are not dispersed by the disturbing environment and thus mist of ink particles is not formed.

[0058]

In addition, in situations wherein the satellite ink particles are generated, the formation of mist can effectively suppressed when the jetted speeds of main ink particles M are controlled so that satellite ink particles combine with main ink particles that are jetted after the satellite ink particles have been jetted. Fig. 6 illustrates typically the principle of suppressing the formation of mist. That is, the respective jetted speeds of main ink particles can be controlled so that satellite ink particles S1 jetted after the main ink particle M1 can combine with the following main particle M2. Thus, the preceding satellite ink particles S combine with the following main ink particle M and then reach the ink absorbing member. Thus, the scattering and dispersing of the satellite ink particles S could be suppressed to a satisfactorily low extent.

[0059]

Fig. 7 shows results of simulation controlled by the foregoing control conditions, in which time (μs) is measured on the horizontal axis and distance (mm) which is necessary for the preceding satellite ink particle to be combined with by the following main ink particle is measured on the vertical axis. In Fig. 7, the continuous line indicates the flying characteristic of a satellite ink particle generated in the preceding ink jetting cycle. The two-dot chain line, the chain line, the short-dash line and the long-dash line indicate the flying characteristics of main ink particle generated in the succeeding ink jetting cycle by using driving signals of 1,000 Hz, 3,600 Hz, 7,200 Hz and 28,800 Hz, respectively.

[0060]

As obvious from Fig. 7, the slopes of the characteristic lines represent speeds of the particles. In this simulation, the flying speeds of the satellite ink particles and the main ink particles are about 4.5 m/s and about 8 m/s, respectively. For example, when the frequency of the driving signal is 1,000 Hz shown by the two-dot chain line, the main ink particle M cannot catch up with the satellite ink particle S jetted in the preceding ink jetting cycle because the period of the driving signal is long. In this case, the satellite ink particle S may float in mist. When the frequency of the driving signal is 7,200 Hz shown by the short-dash line, the main ink particle M catches up with the satellite ink particle S jetted in the preceding ink jetting cycle in a range of 2 mm or less from the nozzles of the recording head because the period of the driving signal is short.

[0061]

The shorter the distance of the region in which the main ink particle M catches up with the preceding satellite ink particle S, the lower is the probability that the satellite ink particles S float, so that the amount of the ink scattered in mist can effectively be suppressed. According to such a condition that the main ink particle M catches up with the satellite ink particles S jetted in the preceding ink jetting cycle in a range of 2 mm or less from the nozzle of the recording head, a preferable result can be obtained as described below.

[0062]

[0063]

Conditions that enables the main ink particle M to catch up with the satellite ink particles S jetted in the preceding ink jetting cycle are expressed by:

$$\{(1/f) + t\} \times V_s \leq t \times V_m \quad \text{..... (expression 1)}$$

$$t = L/V_m \quad \text{..... (expression 2)}$$

where V_m (m/s) is the flying speed of the main ink particle, V_s (m/s) is the flying speed of the satellite ink particle, f (Hz) is the frequency of the driving signal, L (mm) is the distance of the position where the main ink particle catches up with the satellite ink particle from the nozzle, and t (s) is the time

necessary for the main ink particle to catch up with the satellite ink particle.

Substituting Expression 1 into Expression 2,

$$f \geq (V_s \times V_m)/\{(V_m - V_s) \times L\} \quad \text{.....(expression 3)}$$

[0064]

Fig. 8 is a table showing combinations of the flying speed V_s (m/s) of the satellite ink particle and the frequency f of the driving signal determined by using Expression 3, when the control conditions enable the main ink particle flying at a flying speed V_m = 8 m/s to catch up with the preceding satellite ink particle S at a position in a distance of 2 mm or below from the nozzle of the recording head.

[0065]

It is known from Fig. 8 that the main ink particle is able to catch up and combine with the minute ink particle jetted in the preceding ink jetting cycle, even if the flying speed V_s of the satellite ink particle is about 5 m/s or above, provided that the frequency f of the driving signal is 10 kHz or above.

[0066]

Fig. 9 shows the results of experiments conducted to examine the contamination of the interior and the exterior of ink-jet recording apparatus with ink mist, in which the type of the ink and the frequency of the driving signal are varied. In Fig. 9, circles (○) indicate scarcely recognizable contamination, triangles (△) indicate slight contamination, crosses (×) indicate light contamination and double crosses (××) indicate heavy contamination.

[0067]

As obvious from Fig. 9, the degrees of contamination with the cyan ink and the magenta ink are greater than those of contamination with the other inks. However, it was found that any one of the inks cause contamination scarcely when the frequency of the driving signal for the flushing operation is 10 kHz or above. That is, the possibility of mist formation is dependent on the type of the ink. Therefore, the degree of contamination with the ink can be reduced by using driving signals of different frequencies respectively for different inks when necessary.

[0068]

Since, as mentioned above, the different inks have possibilities of different degrees of mist formation, respectively, the degree of contamination with different inks can be reduced by carrying out the flushing operation for some of the inks in the first flushing region in which the capping means is disposed and by carrying out the same for the other inks in the second flushing region opposite the capping means. For example, it is preferable to carry out the flushing operation for the cyan ink and the magenta ink in the first flushing region by the capping means, and to carry out the flushing operation for the black ink and the yellow ink in the second flushing region.

[0069]

As mentioned above, the fan motor for driving the ventilation fan to suppress the temperature rise of the ink-jet recording apparatus is stopped temporarily during the flushing operation, to avoid the dispersion of ink mist. Therefore the degree of contamination with the inks can be reduced. It is desirable that the fan controlling means keeps the ventilation fan stopped at least until the ink particles jetted for the flushing operation arrive at an opposite portion, that is, the ink absorbing member in the embodiment.

[0070]

[Effects of the invention]

As described above, according to a flushing controlling method and a flushing controlling unit in a ink-jet recording apparatus of the present invention, when a flushing operation is conducted to the flushing region, the flushing operation is conducted according to such a driving condition that after a main ink particle is jetted, no minute ink particle is generated or some minute ink particles are generated but combined with the following main ink particle. Thus, the generation of ink mist can be effectively suppressed. Thus, the problem that the generated ink mist may cause the contamination of the interior and the exterior of recording apparatus can be solved, so that an ink-jet recording apparatus whose value as goods is much increased can be provided.

[Simple explanation of the drawings]

[Fig. 1]

Fig. 1 is a fragmentary front view of a main portion of an ink-jet recording apparatus according to the present invention;

[Fig. 2]

Fig. 2 is a block diagram of a control circuit included in the ink-jet recording apparatus shown in Fig. 1;

[Fig. 3]

Fig. 3 is a circuit diagram of the head driving unit shown in Fig. 2;

[Fig. 4]

Fig. 4 shows diagrams showing waveforms of driving signals generated by the circuit shown in Fig. 3;

[Fig. 5]

Fig. 5 is a diagram showing a waveform of a driving signal for explaining a control of rising characteristic of the driving signal generated by the circuit shown in Fig. 3;

[Fig. 6]

Fig. 6 is a sectional view for explaining the relation between a main ink particle and satellite ink particles in a flushing operation;

[Fig. 7]

Fig. 7 is a graph showing the flying characteristics of a main ink particle and satellite ink particles in a flushing operation;

[Fig. 8]

Fig. 8 is a table of data representing dependence of flying speeds of a main ink particle and a satellite ink particle on frequencies of flushing driving signals;

[Fig. 9]

Fig. 9 is a table of measured data representing degrees of contamination caused by mists of different inks;

[Fig. 10]

Fig. 10 is a sectional view of a recording head included in an ink-jet recording apparatus;

[Fig. 11]

Fig. 11 shows fragmentary sectional views of the recording

head shown in Fig. 10 with ink particles jetted in a flushing operation;

[Fig. 12]

Fig. 12 is a fragmentary front view for explaining dispersion of ink mists in a flushing operation.

[Reference numerals]

1. Carriage
4. Carriage shaft
5. Recording head
5c. piezoelectric member
5f. Cavity (pressure-generating chamber)
5m. Nozzle plate
5k. Nozzle
6. Black ink cartridge
7. Color ink cartridge
8. Sheet guide member
9. Recording sheet (recording medium)
10. Capping means (first flushing region)
11. Suction pump
12. Wiping member
13. Opening (second flushing region)
14. Ink absorbing member
15. Absorbing-member housing case (waste ink tank)
30. Printing operation controlling means
31. Head driving means
32. Flushing operation controlling means
33. Cleaning operation controlling means
34. Pump driving means
37. Carriage positioning controlling means
38. Carriage motor
39. Fan controlling means
40. Fan motor
M. Ink main particle
S. Ink minute particle (satellite particle)

[Title of the document] ABSTRACT

[Summary]

[Object]

To suppress generation of unnecessary mist from minute ink particles during the flushing operation.

[Solving Means]

The respective jetted speeds of main ink particles can be controlled so that satellite ink particles S1 jetted after the main ink particle M1 can combine with the following main particle M2. Thus, the preceding satellite ink particles S combine with the following main ink particle M and then reach the ink absorbing member. Thus, the scattering and dispersing of the satellite ink particles S could be suppressed to a satisfactorily low extent. Thus, a problem of contamination in and out the apparatus by the ink mist can be solved.

[Selected Drawing] Fig.6

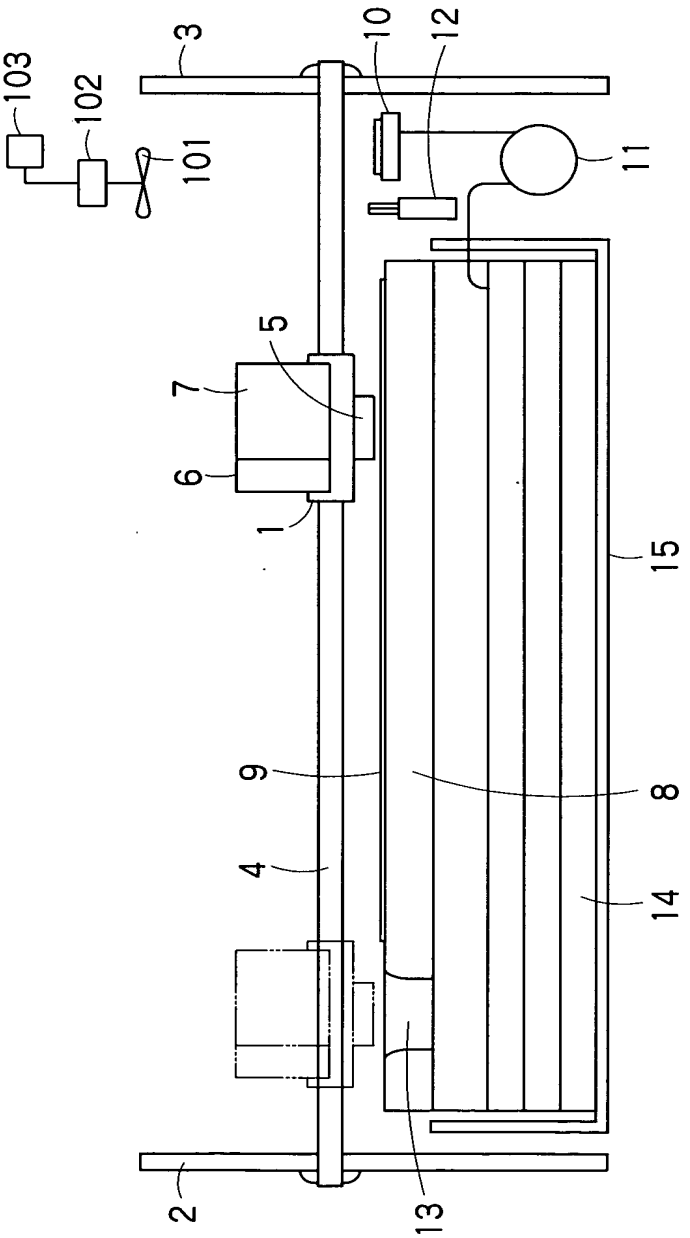


FIG. 1

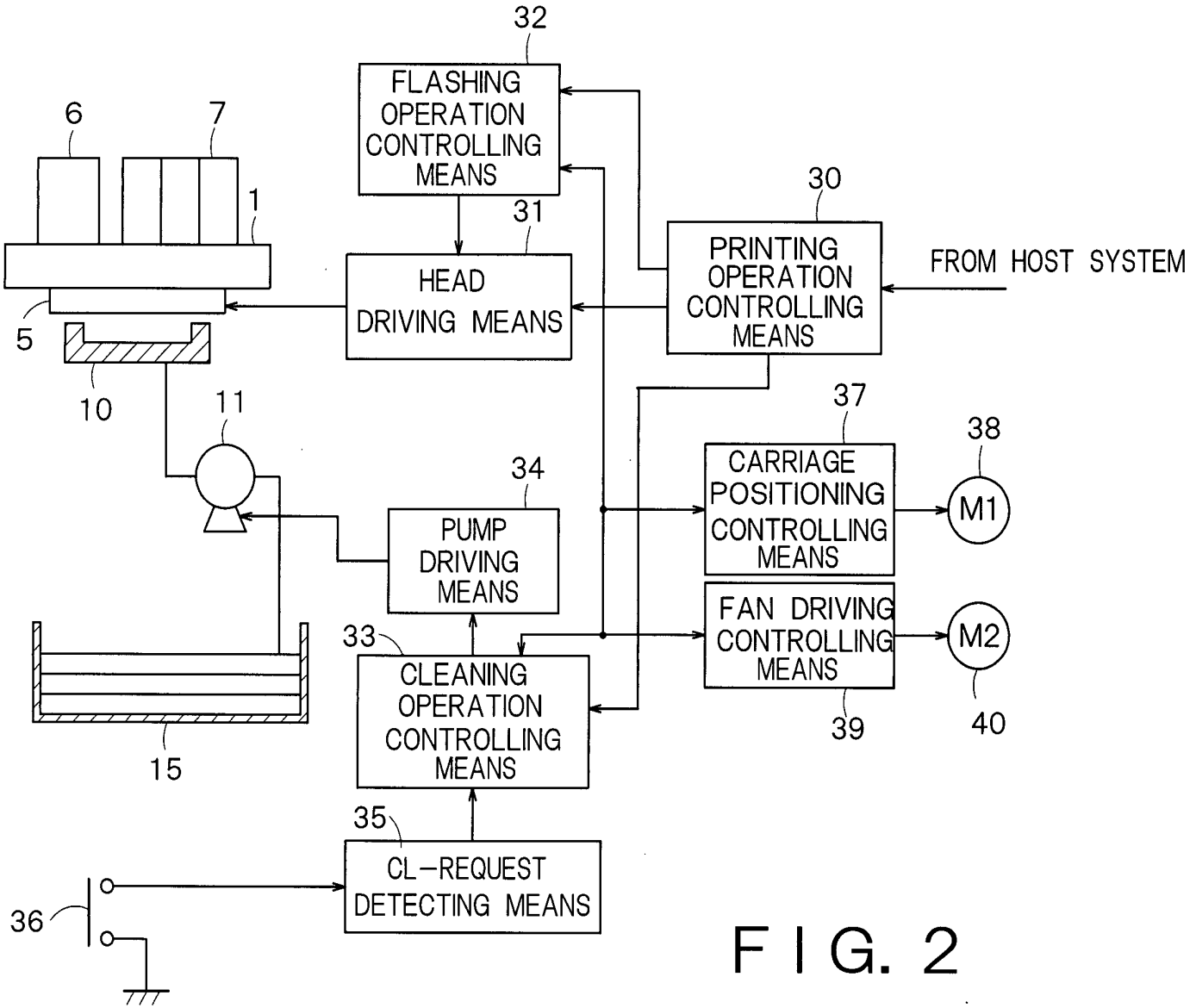

32
FLASHING OPERATION CONTROLLING MEANS
6
7
1
31
30
HEAD DRIVING MEANS
PRINTING OPERATION CONTROLLING MEANS
FROM HOST SYSTEM
5
10
11
37
38
CARRIAGE POSITIONING CONTROLLING MEANS
M1
34
PUMP DRIVING MEANS
FAN DRIVING CONTROLLING MEANS
M2
33
CLEANING OPERATION CONTROLLING MEANS
15
39
40
35
CL-REQUEST DETECTING MEANS
36

FIG. 2

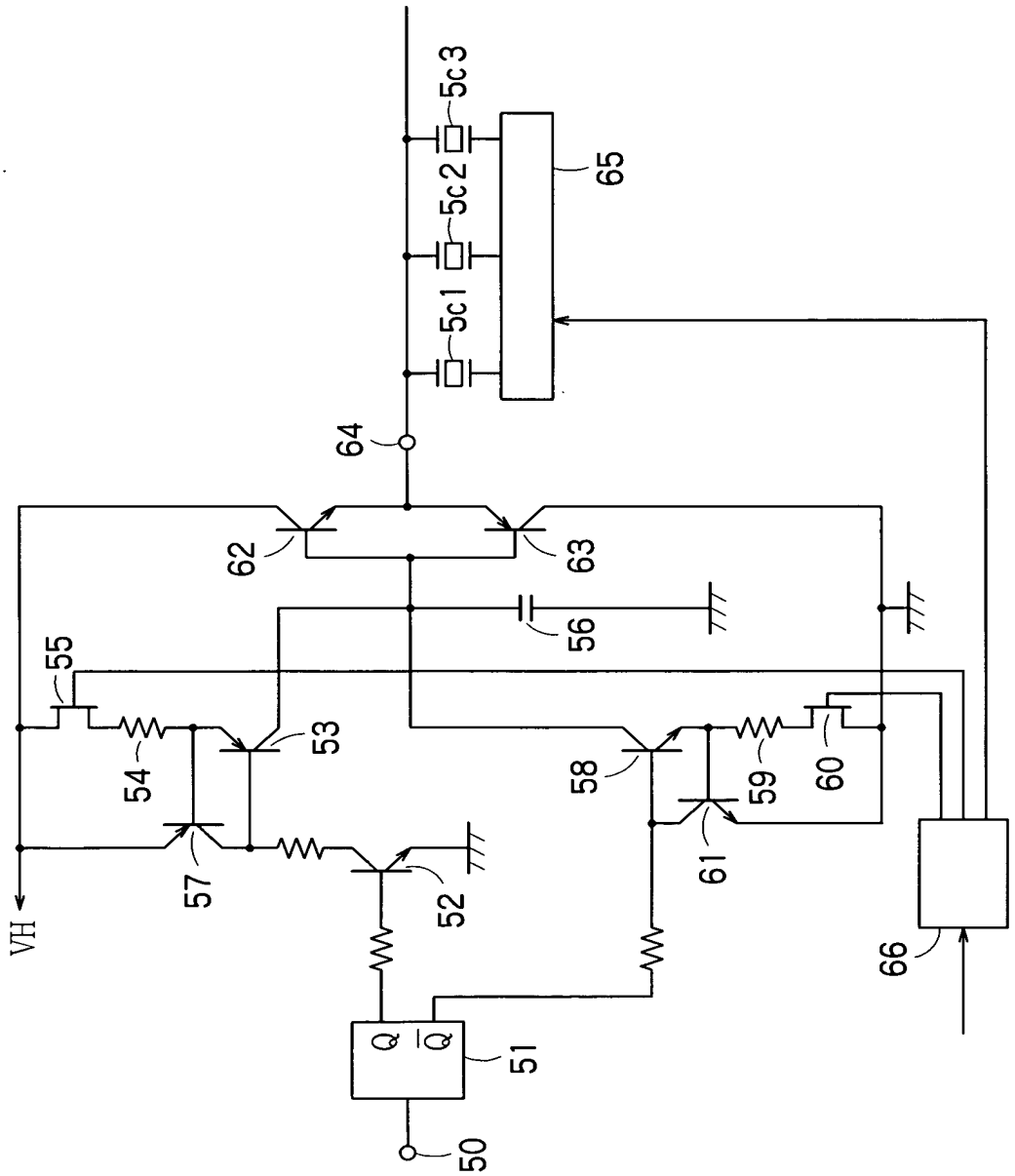


FIG. 3

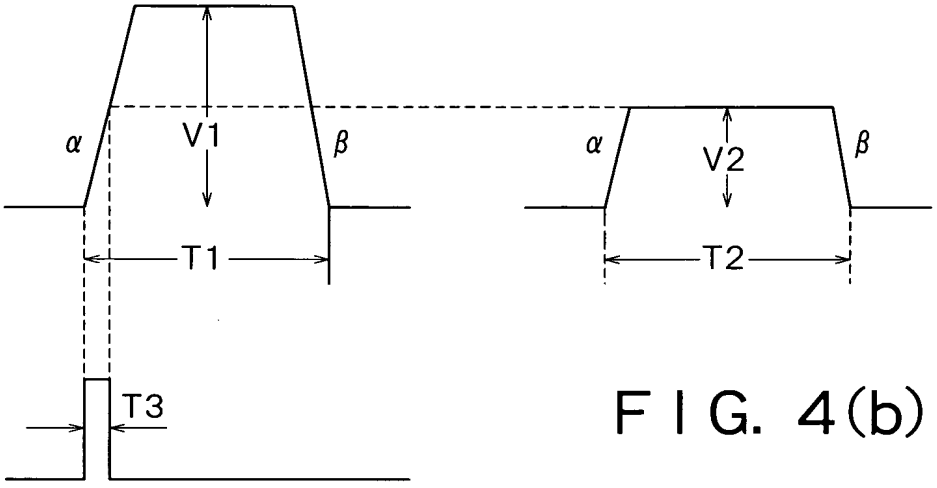


FIG. 4(b)

FIG. 4(a)

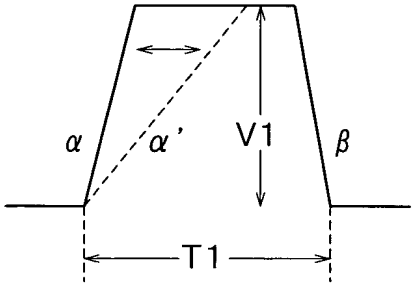


FIG. 5

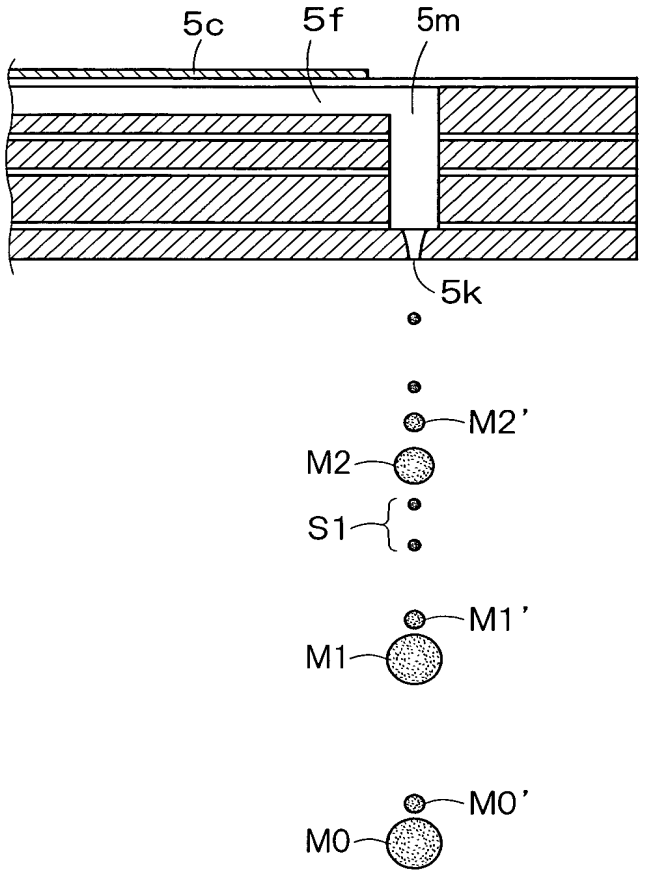
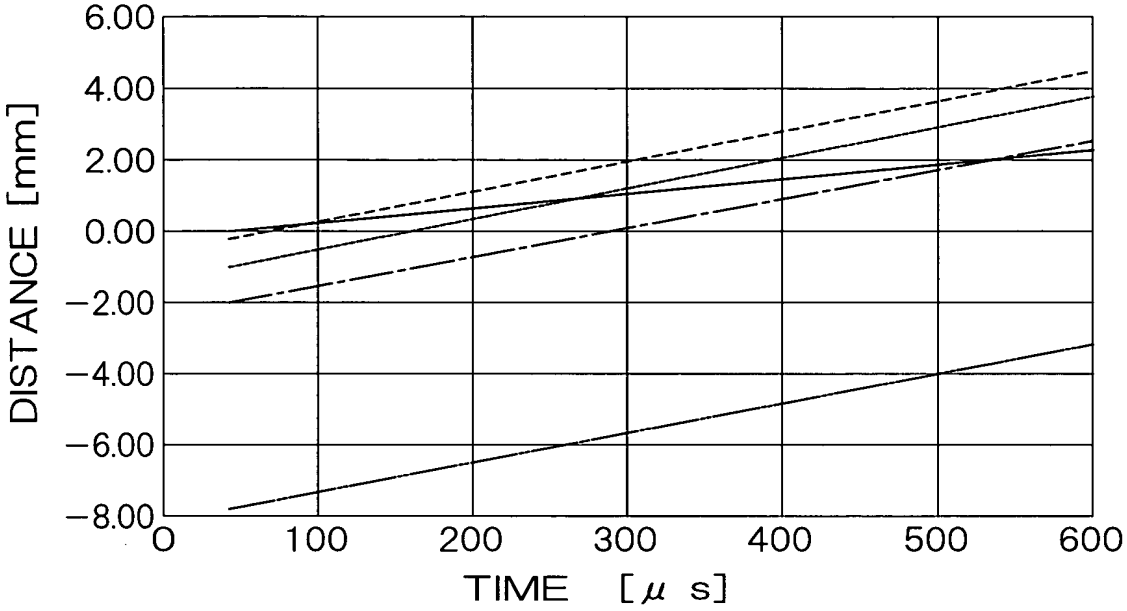


FIG. 6



[EXPLANATORY NOTE]

———— FLYING CHARACTERISTIC OF SATELLITE INK PARTICLES JETTED IN THE PRECEDIG INK JETTING CYCLE

———— FLYING CHARACTERISTIC OF THE MAIN INK PARTICLES JETTED IN THE SUCCEEDING INK JETTING CYCLE BY USING A 1,000 Hz FLASHING SIGNAL

—·——·— FLYING CHARACTERISTIC OF THE MAIN INK PARTICLES JETTED IN THE SUCCEEDING INK JETTING CYCLE BY USING A 3,600 Hz FLASHING SIGNAL

———— FLYING CHARACTERISTIC OF THE MAIN INK PARTICLES JETTED IN THE SUCCEEDING INK JETTING CYCLE BY USING A 7,200 Hz FLASHING SIGNAL

---------- FLYING CHARACTERISTIC OF THE MAIN INK PARTICLES JETTED IN THE SUCCEEDING INK JETTING CYCLE BY USING A 28,800 Hz FLASHING SIGNAL

FIG. 7

Vm[m/s]	8	8	8	8	8	8
Vs[m/s]	7	6	5	4	3	2
L [mm]	2	3	2	2	2	2
f [Hz]	28000	12000	6667	4000	2400	1333

FIG. 8

DRIVING FREQUENCY [Hz]			1000	3600	4800	7200	14400	28800
CONTAMINATION	EXTERIOR	BLACK	×	△	○	○	○	○
		CYAN	× ×	△	△	○	○	○
		MAGENTA	× ×	△	△	○	○	○
		YELLOW	×	△	○	○	○	○
	INTERIOR	BLACK	×	△	○	○	○	○
		CYAN	× ×	×	×	△	○	○
		MAGENTA	× ×	×	×	△	○	○
		YELLOW	×	△	△	○	○	○

FIG. 9

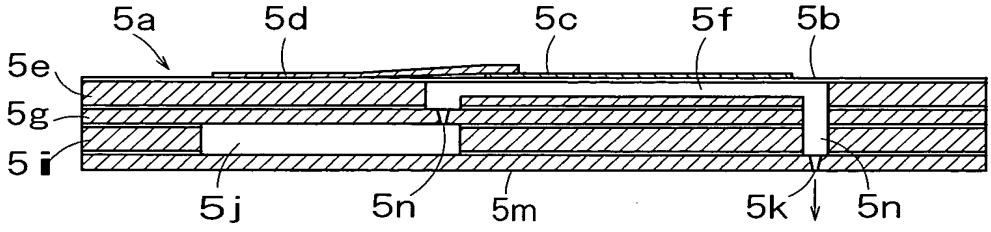


FIG. 10

FIG. 11(a)

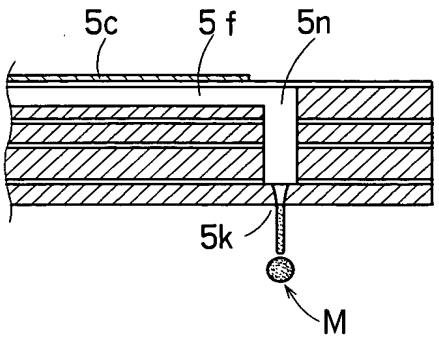


FIG. 11(b)

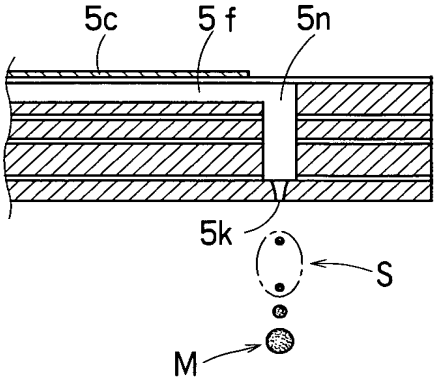
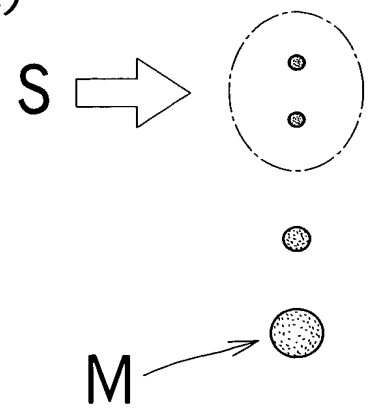


FIG. 11(c)



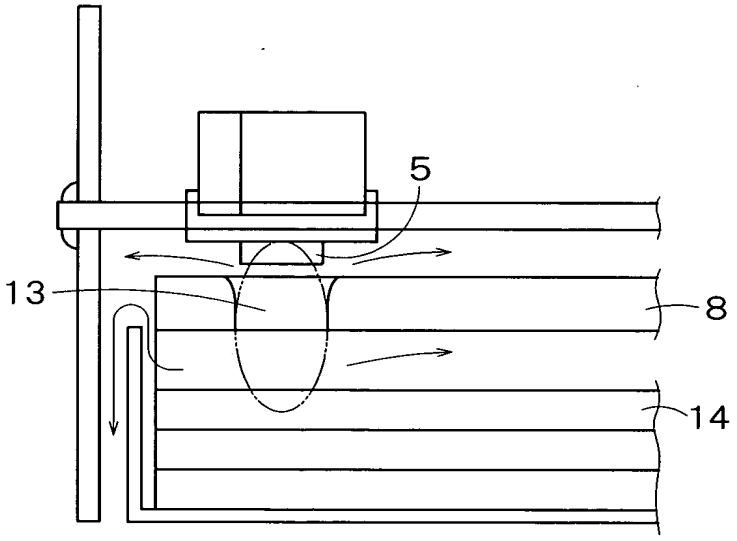


FIG. 12